

# **INSTITUTE AND FACULTY OF ACTUARIES**

## **EXAMINERS' REPORT**

April 2017

### **Subject ST9 – Enterprise Risk Management**

#### **Introduction**

The Examiners' Report is written by the Principal Examiner with the aim of helping candidates, both those who are sitting the examination for the first time and using past papers as a revision aid and also those who have previously failed the subject.

The Examiners are charged by Council with examining the published syllabus. The Examiners have access to the Core Reading, which is designed to interpret the syllabus, and will generally base questions around it but are not required to examine the content of Core Reading specifically or exclusively.

For numerical questions the Examiners' preferred approach to the solution is reproduced in this report; other valid approaches are given appropriate credit. For essay-style questions, particularly the open-ended questions in the later subjects, the report may contain more points than the Examiners will expect from a solution that scores full marks.

The report is written based on the legislative and regulatory context pertaining to the date that the examination was set. Candidates should take into account the possibility that circumstances may have changed if using these reports for revision.

Luke Hatter  
Chair of the Board of Examiners  
July 2017

**A. General comments on the *aims of this subject and how it is marked***

1. The aim of the Enterprise Risk Management (ERM) subject is to instil in successful candidates the key principles underlying the implementation and application of ERM within an organisation, including governance and process as well as quantitative methods of risk measurement and modelling. The student should gain the ability to apply the knowledge and understanding of ERM practices to any type of organisation.
2. The ST9 exam generally requires bullet point form or short form essay style answers that apply general principles to directly address specific circumstances. The answers given below are just one possible set of acceptable answers.
3. Candidates are awarded marks for all reasonable answers including different but still reasonable numerical solutions. Marks are awarded for working in the case of numerical answers.
4. Candidates' answers are made up of a series of points. For example, a point can be stating a valid type of risk, describing the type of risk or (part of) a calculation.
5. Candidates who give well-reasoned points, not in the marking schedule, are awarded marks for doing so.

**B. General comments on *student performance in this diet of the examination***

1. The paper was made up of two long questions.
2. Question 1 covered issues around risk definitions, measurement and management; and question 2 covered risk concentration, regulation and corporate governance.
3. As is common practice, the large majority of the questions were:
  - based on bookwork, and/or
  - based on simplified case studies; and/or
  - loosely based on actual and often relatively recent events.
4. The examiners seek to test the candidate's knowledge of the syllabus. The core reading is an important source for framing questions but not the only source. For this reason, candidates are encouraged to read the financial press and to consider how current news items can be applied to the issues and concepts contained in the core reading.
5. Well-prepared candidates scored well across the whole paper. The comments that follow the questions concentrate on areas where candidates could have improved their performance.

## C. Pass Mark

The Pass Mark for this exam was 59.

## Solutions

### Q1 (i)

- Important to have internally consistent definitions of risk... [1]
- ...such that all risks are covered...
- ... and there is no duplication
- It is important that the risk definitions are expressed in a way which is clear and unambiguous
- Most important point is that all employees have the same understanding that a particular risk has a particular meaning
- In particular to avoid breaching stated tolerances or limits due to a misunderstanding

[½ marks per valid point unless otherwise stated, max 2]

This question was generally well answered.

### (ii)

- As it stands, there are significant differences between BAM's and LIL's definitions
- For example, both firms use the term "credit risk" to mean different things...
- ...with one using it in relation to derivative losses and the other using it in relation to bond losses
- Similarly, market risk is defined differently, with the missing part of credit risk appearing here for BAM [1]
- Default risk for LIL appears to be the same as credit risk for BAM
- Basis risk and mismatch risk appear to be interchangeable
- The measure for market risk is one-sided in both cases
- Currency risk is a standalone risk for BAM, but included in market risk for LIL

[½ marks per valid point unless otherwise stated, max 3]

This question was generally well answered.

### (iii)

- It is important that a consistent taxonomy is adopted for these two firms [1]
- It would probably make more sense for the BAM taxonomy to be adopted...
- ... as BAM is a larger...
- ... and more complex organisation...
- ... and has more complex and credit-risky bond portfolios

- However, LIL's taxonomy could be adopted if it is thought to have greater internal consistency...
- ... or to reflect better the regulatory definitions
- One or other taxonomy may need to be used if there are particularly regulatory requirements (or requirements from a stock exchange or other external shareholder)
- It is also important to consider what else the risk definitions here are used for.
- For example, whether they are used in the process used to pick particular investments...
- ...and if so, whether any change would mean that the effectiveness of the investment management process would be jeopardised
- It may be that a hybrid approach is instead chosen for both entities...
- ... taking the best of both
- It might even be decided that a completely new taxonomy is needed

[½ marks per valid point unless otherwise stated, max 4]

This question was answered moderately well. Many candidates failed to produce a sufficiently large number of distinct points in their answers.

(iv)

- The maximum loss expected...
- ...over a one-day period...
- ...with a 95% probability or level of confidence
- (or an appropriate formula)

[½ marks per valid point, 2 marks for all three points]

This question was well answered.

(v)

- Downside risk is the concept of risk being about loss rather than uncertainty [1]
- In other words, it suggests an asymmetric measure of loss
- This is particularly relevant to bonds because the upside potential is limited (as the best you can do is to get your money back)... [1]
- ... particularly over long time horizons...
- ...whilst the downside potential is more significant (you could lose everything)...
- ...and the expected position is closer to the maximum upside than the maximum downside
- The risk of significant loss is less for a portfolio of credits than for a single bond, due to diversification, but is there nonetheless

- This means that it is important to have a risk measure that captures this asymmetry of returns, i.e. a downside risk measure

[½ marks per relevant point unless otherwise stated, max 3]

This question was poorly answered. Many candidates failed to recognise the relevance of the asymmetric return profile of bonds.

(vi)

- VaR is a one-sided risk measure... [1]
- ...which is appropriate for a bond, where the return profile is asymmetric (as noted in part (v)) [1]
- Volatility is a symmetrical risk measure...
- ...which is less appropriate for measuring bond risk
- VaR concentrates more on the tails... [1]
- ... whereas volatility is about the distribution as a whole
- However, whether the above features are an issue depends partly on exactly how the risk measures are being used... [1]
- ... and the model being used to generate them
- In particular, if the risk measure is being used only to compare bonds...
- ... and the underlying model assumes normally distributed returns, then VaR would be no better than volatility
- ... though this would be a poor model for bond returns
- VaR is not a coherent risk measure...
- ...which means that care must be taken when aggregating the risk for a portfolio of bonds [1]
- Volatility is a coherent risk measure, which helps with risk aggregation
- The one-day period used by BAM is very short-term...
- ... particularly given the likely investment time horizon of BAM's clients
- However, this is likely to be an issue only if the risk measure does not scale with time in a simple way...
- ...in other words, if there is any serial correlation
- Annualised volatility is likely to be a more reasonable time horizon...
- ... for risk measurement for pension schemes
- people may be more used to standard deviation...
- ...although VaR has a more intuitive meaning
- Both VaR and standard deviation look only at quantifiable risks

[½ marks per valid point unless otherwise stated, max 5]

This question was generally not answered well. Candidates often failed to pick up on the relevant information given in the question, which would have been helpful in generating a larger number of points.

(vii)

- Risk capital is held by an organisation to provide protection against adverse events [1]
- The implications of a large loss in a BAM bond portfolio would be negative for BAM... [1]
- ...in terms of reduced fee income...
- ... and the potential loss of clients
- However, these impacts may be only of second order to BAM
- This means that this risk aggregation may not be particularly important for BAM
- The risk would be greater for clients invested in BAM's bond fund... [1]
- ... since they would bear any losses directly
- Risk aggregation is important here because the impact of losses at the portfolio level is more important than the losses on individual securities... [1]
- ...so it is important that risk is aggregated correctly
- However, this will not necessarily provide a comprehensive answer to clients...
- ...as they may have other investments in addition to money with BAM...
- ...and they may be measuring losses relative to liabilities (for which bonds could be a match) rather than in absolute terms [1]
- Risk aggregation can allow for interdependencies between bonds to be modelled [1]
- And similarly diversification benefits...
- ... which can reduce the amount of capital that needs to be held

[½ marks per valid point unless otherwise stated, max 5]

<p>This question was poorly answered. Again, some candidates struggled to find a broad enough range of distinct points.</p>
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(viii)

- By offering shares, BAM is trying to make sure that the LIL management is incentivised to continue to work towards the profitability of the company [1]
- And to reduce the potential for agency risk
- BAM might feel that offering shares would increase the probability of the managers staying with the company, as they would feel more tied to it...
- ... and so shares rather than cash would increase the chance of retaining knowledge in the company.
- By delaying payment for a number of years, BAM is hoping to ensure that the management of LIL continue to work towards profitability at least until the shares *vest*. [1]

- Using shares means that there is less need for BAM to come up with a large amount of cash.

[½ marks per valid point unless otherwise stated, max 2]

This question was generally well answered.

(ix)

- Working towards short-term profitability does not necessarily equate to driving towards the best long-term interest of the firm
- In theory, LIL management could use options to hedge out the share price risk
- With BAM being big, management might not feel that they could impact profitability

[1 mark for any valid point]

Candidates generally either scored full or no marks here, depending on whether they were able to make one of the points above.

(x)

- Reward for expected defaults – the amount of the spread required to compensate for the expected level of future defaults [1]
- Risk premium / credit beta – reward for uncertainty over future level of expected defaults [1]
- Liquidity premium – reward for the fact that it might not as easy to sell (or at least to sell at an acceptable price) a corporate bond when funds are required [1]
- Trading cost – compensation for the additional cost of trading corporate bonds relative to gilts
- Skew – reward relating to skewness of corporate bond returns if investors dislike losses more than they like gains
- Tax – reward for fact that corporate bonds may be less tax efficient than gilts
- Spread volatility – reward for uncertainty over spread
- Reward for fact that gilts can be used as collateral with derivative contracts

[½ marks per valid point unless otherwise stated, max 4]

Many candidates scored reasonably well here, but a large number struggled to make a significant number of distinct points.

(xi)

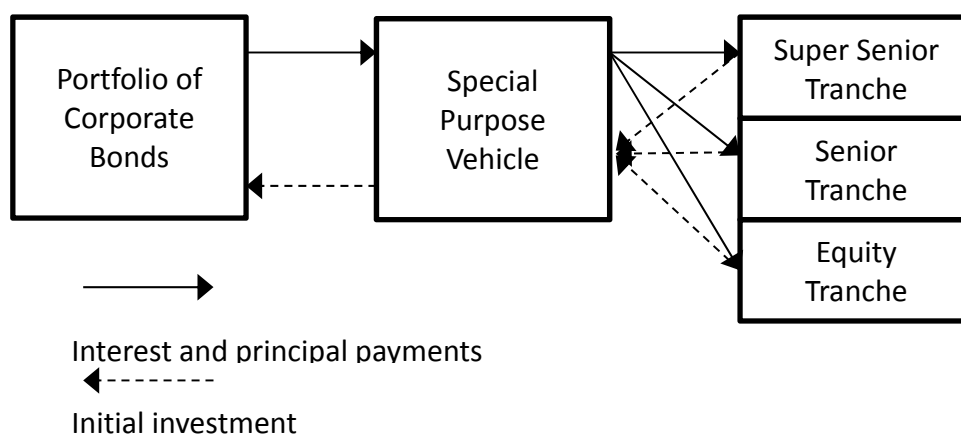
- May be to reduce credit risk
- More likely used to take advantage of potential mis-pricing of corporate bonds...

- ...particularly at lower grades
- Allows investors with a range of different risk preferences to take advantage of this mis-pricing
- Relies in particular on the liquidity premium...
- ... and the fact that it is typically higher for certain credit grades
- Also relies on the CDO being sufficiently diversified to profit from defaults that are in-line with expectations...
- ...rather than being damaged by macro events that affect all credits to the same extent

[½ marks per valid point, max 2]

Candidates struggled with this question.

(xii)



[3]

Although a number of candidates scored full marks on this question, many scored poorly on what should have been a simple bookwork question.

(xiii)

- The correlation between securities... [1]
- ... including the shape of the correlation...
- ... particularly in the tails...
- ...and hence the broader choice of correlation approach (e.g. the copula)
- This is linked to the choice of securities included ... [1]
- ...and the number of securities used (which is given here)...
- ...and who gets to choose the securities...
- (which is not always the asset manager, sometimes the end investor)
- Also need to consider implications for the price
- Investor preferences/expectations [1]



- Level of investor demand
- Attachment points offered by other CDOs

[½ marks per valid point, max 4]

This question was very poorly answered, with many candidates making only one or two valid points.

(xiv)

- Banks must hold capital in respect of the risks that they face
- Among these risks, one of the most important is credit risk...
- ... coming mainly from loans made by the bank...
- ... to individuals (e.g. mortgages) and businesses
- The amount of capital required is determined by the number and quality of loans written...
- ...and the payoff profile of the bank's interests in the loans
- Although the bank can reduce its capital requirements by reducing the number of new loans it makes (or increasing their quality)...
- ...or by selling on the existing loans...
- ... it may not wish to follow these routes for profit reasons
- It might therefore try to package them in such a way that it is able to retain a portion of the risk (or return)...
- ...in such a way that the total return as a proportion of the capital used is as high as possible [1]
- The bank may simply convert some of its loans into securities (collateralised loan obligations, a form of CDO)
- And hence remove them from its balance sheet completely [1]
- Passing risk to other parties through the CDO will reduce the bank's capital requirements [1]

[½ marks per valid point unless otherwise stated, max 3]

Many candidates made a reasonable attempt at this question, but few picked up the most important points.

(xv)

- Issue/redeem equity capital
- Change the volume of business written
- Change the mix of business written
- Change the pricing of business
- Merge with/acquire another company
- Change asset types held or degree of asset/liability matching
- Change underwriting/due diligence practices
- Change general level of risk management controls/governance

- Could change the confidence level for the economic capital calculation
- (any other sensible suggestions)

[½ marks per valid point, max 2]

[Total Max 45]

This question was well answered by most candidates.

**Q2** (i)

- Z grain is a key commodity in Hiponia and so a failure can cause contagion effects [1]
- The population loses its main food source from Z1 and Z3
- The population must rely on alternative domestic foods...
- ...and imported foods
- Increased demand pushes prices (of these other sources) up [1]
- The cause of the failure may not be exclusive to Z grain so other crops may have failed
- This further reduces supply, increasing prices further
- Z grain crops may have failed in other countries, increasing import prices further
- There may be pressure on government funding
- If the government is unable to support the population, this may lead to famine
- The population loses its main power supply from Z2 and Z3
- There could be scheduled blackouts
- Crime rates may increase as security systems are unable to operate
- Healthcare standards may decrease
- This could happen because people do not store foods and medicines correctly...
- ...or hygiene standards fall in homes and hospitals (any sensible example)
- Financial institutions, manufacturing and service industries all experience lower productivity due to a lack of power [1]
- They may only be able to operate in the daylight hours and need to use manual alternatives
- Large numbers of farmers may become bankrupt
- Businesses may fail as costs increase and output decreases [1]
- Unemployment will rise as people are made redundant or their hours are reduced
- However, there may be alternative employment as alternative fuels/foods are developed
- Businesses may try to borrow money to cover the increased costs and lower revenues
- Interest rates may increase sharply
- The government has less tax revenue
- The compounding impacts of both the loss of food and power exacerbate the impacts [1]

- Inflation may rise sharply as the cost of food and power has increased [1]
- However, incomes may have fallen
- There may be a run on the bank as people try to buy alternative power sources and food which has become more expensive
- The government will lose export revenue from Z3
- Combined with the increased the demand for imported alternative foods and power sources, this means that...
- ... the currency will devalue sharply [1]
- The whole continent has become reliant on Z3 so will face a crisis [1]
- The continent will have to develop alternatives to using Z3
- So there will be less demand for Z3 when the harvest returns to normal levels
- The government may run out of money trying to support the population and face bankruptcy or collapse [1]
- The government will need to take action to prevent an economic downturn
- There may be social and civil unrest when people are unemployed, hungry, running out of money, etc.
- The government may be removed / there may be political turmoil
- There may be increased emigration
- There may be a lag on the impacts, depending on the amount of grain stored in the country
- The government may need to ask for international aid
- The impacts may themselves adversely impact tourism and thus the income obtained from it

[½ mark each – and for any other valid, distinct points  
– unless otherwise stated, max 10]

This question was well answered by most candidates.
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(ii) (a)

- Financial market risk is the risk arising from changes in investment market values in relation to assets in which Nettle Insurance invests, e.g. equities, bonds and derivatives.
- Interest rate risk is the risk arising from changes in interest rates, and Nettle Insurance may have loans, issued debt or invested in bonds (or may affect customer propensity to purchase).
- Credit risk is the risk that a counterparty may default on an agreement or the risk of variations in credit spreads, e.g. Nettle Insurance may have issued debt or invested in bonds and be exposed to changes in credit spreads
- Foreign exchange risk is the risk that arises due to movement in foreign exchange rates, e.g. Nettle Insurance may have foreign investments or customers outside Hiponia
- Insurance risk is the risk that the timing, frequency and/or severity of an insured event varies from the expectations of the firm at the time of

underwriting or pricing, and Nettle Insurance is exposed to significant risk in relation to crop failure and yields.

- Market demand risk is the risk of lower sales or profit margins arising from changes in market conditions, where “market” refers to the market into which the company’s products are sold, e.g. risk of significant fall in sales of insurance policies.

[1 mark per risk description;  
give ½ mark if not sufficiently well tailored or described, max 3]

(b)

- Operational risk in relation to the risk of losses resulting from inadequate or failed internal processes, people and systems, due to the fact that Nettle Insurance writes complex insurance policies, handles client money and carries out investments
- Operational risk in relation to external events (or catastrophe risk), such as business continuity risk or disaster risk: the risk that an external event such as a natural disaster (e.g. hurricane) affects the physical ability of Nettle Insurance to carry on business at its normal offices.
- Liquidity risk is broadly risk relating to managing short term cash flow requirements and funding e.g. Nettle Insurance may not have enough liquid assets to pay premiums as they fall due. *[NB may also be classified as OK to quantify]*
- Reputational risk is the risk that event or circumstances have an adverse impact on an organisation’s reputation or brand value, e.g. farmers may boycott Nettle Insurance if there were some sort of scandal.
- Counterparty risk is the risk that another party to a transaction or agreement fails to perform its contractual obligations including failure to perform them in a timely manner, e.g. Nettle Insurance may have sales agents that fail to pass on premiums in a timeline manner, or suppliers that fail to deliver goods, for example. *[NB may also be classified as OK to quantify]*
- Other risks such as regulatory risk, strategic risk, political risk, project risk, agency risk, legal risk are all valid examples

[1 mark per risk description;  
give ½ mark if not sufficiently well tailored or described, max 3]

This question was generally answered well.
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(iii)

- The main factor to consider is the need to meet the minimum amount of income objective \$R
- The farmer will buy insurance to protect the minimum amount of income, not more than that [1]
- M and \$Y are set separately for each of the three Z grains so may not need to buy insurance on all three [1]

- The farmer should consider the likelihood of all three or two Z grains failing in the same harvest... [1]
- ... and the relative cost of cover on each Z grain [1]
- And consider whether any discount is offered on the cost of cover (or premium) if more than one crop cover policy is purchased.
- When crops fail the supply is lower so price is higher...
- ... so need total cover for less than the value of M which would be required at current prices
- Farmer's own assessment of the probability of failure [1]
- Which may be lower than Nettle's so the premium may be excessive...
- ... or it may be higher than Nettle's so the premium may be cheap
- May consider past history of crop failures...
- ... if sufficient data is available
- Also could consider expert views on probability of failure over coming year
- E.g. any known disease threats...
- ... or implications of climate fluctuations/trends
- The premium will include a profit margin to the insurer
- The farmer should consider insurance products offered by other insurance companies...
- ... and alternative products like weather options
- And how the premium and cover for these alternatives would compare with Y and P
- The farmer could also consider whether he/she could sell options on the crop
- The farmer should consider whether there are any concerns about Nettle's concentration risk
- Or service standards (or reputation of the company)
- Or financial strength
- The farmer should consider whether he has a preferred split of \$R between the three crops
- And what the implications are of falling below \$R
- Terms and conditions/contract wording

[½ marks per point unless otherwise stated, max 6]

Most candidates scored reasonably well on this question, but many struggled to come up with a sufficient number of distinct points.

- (iv) (a)
- The legislation is contained in the Sarbanes-Oxley Act. [1]
- (b)
- It strengthens the power of the audit function
  - The length of appointment of an audit partner within a firm is limited...
  - ... to five years

- It restricts the provision of audit and non-audit services by the same firm to the same client.
- It requires non-executive directors on audit committees
- A Public Company Accounting Oversight Board has also been established...
- ...to oversee the audit of public companies.

[½ marks per point, max 2]

Many candidates scored well here, but a number missed out on what should have been a straightforward bookwork question.

(v) *Company structure*

- The Board has a responsibility to ensure financial reports and disclosures are accurate... [1]
- ... and so needs to set a culture that emphasises the importance
- Nettle Insurance could establish an audit committee to oversee the financial reporting of the company [1]
- The audit committee should consist of non-executive directors...
- ... including independent non-executive directors
- The internal audit function would need to be independent of any financial reporting within the company... [1]
- ... and report into the audit committee
- An independent external auditor would also be employed to regularly audit Nettle Insurance [1]
- The manager of the Risk Function could be designated the Chief Risk Officer, if this has not already been done
- Nettle Insurance could establish a risk committee...
- ... chaired by the CRO...
- ... responsible for implementing and maintaining the ERM framework
- ... and ensuring that regulatory and accounting requirements are met
- The Risk Function needs to work effectively with line management
- e.g. through using a partnership model

*Policies and processes*

- Nettle Insurance is a small company so it may set only set a small number of key policies
- A risk management policy should be set and implemented
- ... an accounting and financial reporting policy should be implemented [1]
- ... and tested by the internal audit function
- Nettle Insurance should ensure it has a strong risk management culture
- And one where openness is encouraged and valued
- Nettle is a small company so could use this to its advantage to implement new culture or process quickly

- A do, check, review process should be followed for all financial processes to encourage segregation of duties
- Approval of large (greater than pre-defined limits) transactions should be subject to additional controls [1]
- Teams should be incentivised to raise and manage risks or potential accounting concerns [1]
- Risk-adjusted performance measures should be used
- Adhering to regulatory and accounting standards could be a performance objective for all staff [1]
- ... with bonuses linked to performance or prizes for raising and managing regulatory/accounting risks
- Nettle Insurance is a mutual company so risk measures may be linked to solvency rather than profit
- Regular training should be mandatory for all staff...
- ... particularly those working with financial information [1]
- More regular internal management accounts (and other relevant management information) could be produced to highlight issues more quickly [1]
- The risk management control cycle should be utilised
- ... such as identification, whenever a new regulation is published it should trigger an action
- ... assessment – confirmation from the regulator and an impact assessment
- ... management/mitigation including updated processes and training
- ... monitoring including review to ensure the new regulation has been implemented appropriately
- ... modification of the risk taxonomy and any further processes if required
- Accounting risks should be added to the risk register, if they have not already been identified [1]
- Although Nettle Insurance company has no shareholders and no stock market listing requirement it may still decide to report and publish accounting information in line with good market practice (i.e. increased disclosures)
- Good risk management includes open and regular communication with stakeholders...
- ... including the regulator/accountancy body [1]

[½ marks per point unless otherwise stated, max 12]

Most candidates scored reasonably well here.
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(vi)

- If Nettle Insurance has good controls then the frequency of fraudulent activity should be low...
- ... but the severity of the loss when fraud does occur can be high
- The lognormal distribution is fat tailed and skewed so shares these features [1]
- There is no upside to fraud risk...

- ... and the lognormal distribution is one sided
- So the lognormal distribution may be suitable
- However, given the scarcity of data extreme value distributions may be more appropriate (or any other valid approach, e.g. scenario testing)

[½ marks per point unless otherwise stated, max 2]

This question was generally well answered.

(vii)

- Inadequate training could make the impacts of regulatory change more serious, due to lack of preparedness to implement the changes
- Regulatory change could give rise to opportunities for inappropriate accounting by opening up “loop holes” which could be exploited
- Regulatory change could give rise to increased potential for fraudulent activities (as above)
- Infrastructure failure could lead to short-cuts or approximations having to be taken and hence more opportunity for inappropriate accounting
- Inadequate training could lead to infrastructure failure due to mis-use of the infrastructure
- Inadequate training could give rise to human error and misunderstandings leading to inappropriate accounting
- Inappropriate accounting may have been the result of fraudulent activity, i.e. it was deliberate rather than unintentional

[1 mark per valid example, ½ if description is too high level.  
Many other solutions possible max 4]

This question was well answered.

(viii)

- There may be changes over time as the risks evolve in line with changes in environment
- There may be changes over time as the risks evolve in line with changes business mix
- It is also likely that dependencies will vary in the tails (i.e. extreme events)
- In particular, dependencies or correlations are often heavier in the tails [1]
- Under-stating the (tail) dependencies or correlations in the modelling performed could under-state the risk exposure
- This is particularly important in relation to tail dependencies, since regulatory/economic capital tends to be set in the tails [1]



- And in relation to operational risks, which often tend to be “extreme” (high severity, low frequency) events

[½ marks per point unless otherwise stated, max 3]

Most candidates gained some marks on this question, but missed the main points.

(ix)

- The independence copula assumes the marginal distributions are independent. [1]
- In this case there are dependencies between the five operational risk factors so the copula is not appropriate [1]
- The counter-monotonicity (maximum) copula assumes the marginal distributions of one factor is one less the marginal distributions of the other (i.e. full negative dependence) [1]
- The maximum/minimum copula only exists in the bivariate case
- We have five risk drivers so the copula is not appropriate
- The co-monotonicity (minimum) copula assumes the marginal distributions are monotonic transformations of each other (i.e. full positive dependence) [1]
- It is unlikely in this case that the operational losses are fully dependent here
- e.g. that losses due to regulatory change are simply monotonic transformations of the losses due to loss of infrastructure, etc.
- ... so the copula is not appropriate
- The Gumbel copula assumes upper tail dependence but no lower tail dependence... [1]
- ... so that as the risk factors increase the dependency increases and extreme positive values occur together
- If losses were modelled as positive values then the copula could be appropriate [1]
- The Frank copula assumes neither upper nor lower tail dependence [1]
- But has a simple closed form solution...
- ... making it easier to compute
- It is likely that some tail dependence is observed for these types of risk
- So the copula is not appropriate
- The Clayton copula can assume only lower tail dependence...
- ... or no tail dependence...
- ... so that as the risk factors decrease the dependency increases and extreme negative values occur together

- As it is likely that losses from the five risk factors could occur together then the copula could be appropriate [1]
- The Generalised Clayton assumes both upper and lower tail dependence [1]
- ...so that fat tails exist for both extreme high and extreme low risk factors
- Fat tails for extreme highs are expected for these types of risks
- And extreme lows are also likely
- It is possible that if the risk of infrastructure failure is near zero and fraudulent activity is near zero there is a compounding lower operational risk, for example
- The copula could be appropriate
- The Gaussian copula has no tail dependence [1]
- ... but instead of a single correlation coefficient has a matrix of coefficients to help describe the relationships between pairs [1]
- It requires more data to parameterise it
- The copula could be appropriate
- The Students'  $t$  copula has tail dependence
- ... but allows the strength of the dependence in the tails to be varied [1]
- ... and so has more parameters
- ... and more data required to parameterise it
- The copula could be appropriate

[½ marks per point unless otherwise stated,  
up to a max of 2 per chosen copula, overall max 6]

This question was moderately well answered by most candidates.

(x)

- Any except the minimum, maximum, independence, Frank or Gaussian copula could be recommended [1 mark for sensible copula choice]

*[NB justification is not required to gain the full mark, since the question has only asked for the recommendation.]*

Most candidates scored full marks here.

(xi)

- Scenario analysis may be used
- ... based on historical data or
- ... hypothetical scenarios defined internally
- ... with expert input
- ... to define correlations
- ... or to directly assess the aggregate risk

OR

- An implied capital approach may be used
- ... where the overall risk capital at a given level is assessed for all risk in Nettle Insurance
- ... the capital for other risks is subtracted (credit, market, insurance etc.)
- ... and the remaining risk capital is assumed to be operational risk
- ... ignoring interactions like diversification benefit

[½ marks per point, max 2]

[Total Max 55]

Candidates struggled to make a sufficient number of points here.
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**END OF EXAMINERS' REPORT**